CHAPTER 3. SITE INVESTIGATIONS

Introduction

Methods of investigation and testing of soil conditions along a channel system are discussed in this chapter. The purposes of these investigations and testing are to evaluate the resistance of the soils in the bed and banks of the channel to erosion forces, to evaluate the sediment transport relationships, to determine slope stability against sloughing and sliding, to estimate earth loads that may act on structural members, and to determine the rate of water movement through the soils.

The procedures include identification, sampling, and testing or evaluation of stratigraphic units encountered in the channel system to be modified and an evaluation of the sediment transport characteristics of the system.

Investigation Requirements

There are conditions specific to investigations for channel improvements that cause them to differ from investigations at other types of construction sites. One usually significant difference is that channels may extend for many miles through a variety of materials. This fact demands that data obtained from any one test hole must be correlated on as knowledgeable a basis as possible with data obtained at the next test hole, both upstream and downstream. A distinguishing feature of investigations for channel improvements is that almost always they are located in alluvial material. The stability of channels is affected by watershed conditions upstream that control the availability of bed material, and by ground-water conditions at the site. A similarity with foundation investigations for other structure sites exists in that the in-place characteristics of the soil materials are very important if these characteristics that pertain to erodibility differ from those that exist when the material is disturbed.

The following sequence of work is needed to appropriately recognize the conditions specific to investigations for channel improvements while ensuring that an adequate amount and type of data are obtained.

1. Determine the geomorphology of the deposits in which the channel is to be located to the limit necessary for this purpose.

2. Identify stratigraphic units along the proposed channel route and to a depth of at least three feet below the invert or channel bottom elevation as proposed. A stratigraphic unit is defined in this instance as an identifiable stratum of alluvium or other soil material whose susceptibility to erosion is a reflection of the original materials, mode of accumulation and the changes that have occurred since deposition or soil formation.

3. Log soils within stratigraphic units and classify and sample for evaluation or determination of erodibility characteristics.

Geomorphology of Deposits

Significance of the Stratigraphic Unit

There are a number of factors which influence the erodibility or stability of soil materials. Erodibility and stability are explained in this context as responses of the soils to the environment of channel boundaries. Erosion results from the flow of water against the boundary as expressed by mean velocity, tractive force, or a combination of these parameters such as tractive power, the product of mean velocity and tractive force. Instability of stream banks often results from internal seepage forces. The soil's ability to resist erosion is affected by the kinds, amount, and character (dispersive or aggregated) of clay, the amount and size distribution of coarse particles, and the nature and amount of cementing agents. The term coherent is used to describe soils that resist erosion as a mass because of bonding action of clay, cementing agents or other causes. The climate and age of the deposit since its accumulation have a strong bearing on these erodibility characteristics. There is an almost infinite variation that can occur in each of these factors and in their influence on the others. Deposits change with geologic time. Each change produces an expression of the dominant factor and interfactor relationships persisting at that time. Thus, a combination of forces acting on a deposit produce a layer of material identifiable as a stratigraphic unit. Relative uniformity of location in an alluvial profile, uniformity of appearance, and erodibility are a result of a similarity in source of materials, the history of deposition, and the weathering characteristics associated with the areas. In time, with certain exceptions, weathering, consolidation, cementation, accumulation of humus or other influences increases the significance of structure on erodibility. By the same token the significance of local variations in texture is diminished.

The delineation of stratigraphic units simplifies the field investigations in that the units may extend for distances that can include the entire route of channels to be improved. Their thickness and depth below the surface may be relatively uniform and consistent, providing a means for correlation and representative sampling. At the other extreme, alluvial fan deposition can result in a heterogeneous mixture of sand, silt and gravel where correlation of individual beds may be not only impossible but not particularly useful.

Identification of Stratigraphic Units

The origin of the defined stratigraphic units as alluvium dictates that certain relationships existed between the deposits and the carrying capacity of the stream at the time. Further, the relationships that exist today are not necessarily the same as at the time the sediment was deposited. For example, during portions of the Pleistocene, runoff and sediment transport were on an appreciably larger scale than at present.

The primary identifying characteristics of a stratigraphic unit are: color, thickness, grain size distribution, texture, structure, plasticity, consistency, density, dispersive characteristics and cementation. Slight variations that may occur do not necessarily signify the presence of a new stratigraphic unit, particularly if the deposits are conformable with units above and below the one being described.

The location of stratigraphic units areally within the alluvial valley is as important as their position and identification within the vertical profile. Because most alluvial channels meander about within a relatively short geologic time period, it is probable that stratigraphic units in a valley confined by side slopes will be at about the same elevation across the valley. This requires field checking before assuming a uniform valley-wide distribution of stratigraphic units exists.

Geomorphic History as a Determinant of Erosion Resistance

The history of the stratigraphic unit from the moment of deposition determines its erosion resistance. The grain size distribution and texture of the deposit is initially the most important characteristic and it may remain so if the environment following deposition is not conducive to modifications tending to change the arrangement or bonding of particles. These modifications can be produced by one or a number of post depositional changes such as the movement downward of particles from the overlying deposits, by weathering, by consolidation or chemical action that increases or decreases the bond between particles.

The result of this geomorphic history is that the stratigraphic unit responds in characteristic manner to the hydraulic forces that may be exerted against its exposed profile. The unit may remain as individual particles free of any bond with adjacent ones, or it may resist as a mass due to coherence between particles. The bond between particles that may be reflective of a long history in a particular environment may be destroyed when the profile is disturbed.

The following is an example of the depositional and environmental influences that can affect the erosion resistance of a stratigraphic unit. A sequence of stratigraphic units may indicate that in this instance they are alluvial deposits consisting of (1) light colored, finely stratified noncoherent silt and fine sand about two feet thick. Below this unit there is (2) a compact dark gray clayey silt horizon several feet in thickness. Then there is (3) a layer of gravel in a matrix of compact brown silty clay that starts a foot above the stream bed in the exposed banks and extends below the streambed and the proposed invert grade to unknown depths.

The reasons for a uniqueness in character of stratigraphic units within a profile are several fold. Taking the profile cited above as an example, the number 1 stratigraphic unit of this hypothetical profile is an accumulation of recent sediment. Soil forming processes have not had time to modify the sediment's characteristics over that contributed by the texture and grain size distribution of the transported sediment and its mode of deposition. The bulk of unit 2 accumulated either as a mixture of, or dominantly of, lateral accumulation as the stream meandered or vertical accumulation during overbank flooding. The developed soil in this unit indicates a following period relatively free of deposition or erosion. Time was available for limited weathering of the sediment, and for humus to accumulate. The gravel layer identified as unit 3 was deposited at a time of relatively high velocity flow. The high discharges that brought down the gravel could have formed a braided wash that extended from one side of the valley to the other. During flows of lower velocities fine sediment was deposited and migrated into the gravels. With age and weathering of clay forming materials this stratigraphic unit, with its characteristic erosion resistance properties, evolved.

The sediment source, texture, and mode of deposition of units 1 and 2 could be very similar, yet their appearance including color, degree of consolidation, and erosion characteristics can be quite different. These differences created by changes occurring since deposition can vary widely depending upon the interaction of the average annual climatic environment: humid or arid, cold or hot. The climate following deposition can create a wide change in erosion characteristics for different reasons. In a humid hot climate, textural changes can occur by weathering of clay forming minerals, leaching of soluble salts, carbonates, etc. or by movement of fine clay-size particles from the upper to the lower profiles. Structural changes can be caused by alternate wetting and drying, and consequent swelling and shrinking, as well as by growth and decay of vegetation.

In an area affected by a permanently high water table, little or no post-depositional changes in the deposits may occur. This is especially the case when there is little oxygen in water in which the stratigraphic unit is submerged. The reason for this is that oxidation essential to the weathering process has been prevented or retarded. Reduction of iron, resulting in grayish, greenish, or bluish coloration, however, can occur. Thus sediment which may give the appearance of being recent in origin could have been deposited at about the same time as a nearby unit with a profile containing morphological evidence suggestive that it has been in place for a long period of time.

Accumulations of or cementation by silica or carbonates, or both, can change the structure and erosion resistance of the sediments without changing the engineering classification materially because the cementing material may not noticeably add to the finer soil constituents.

The junction with tributaries can change the uniformity of main stream stratigraphic units, depending upon whether the tributary has been or is a significant contributor of sediment. The type of sediment deposition may be so similar to the main valley deposits that interfingering or mixing results in an accumulation that is not separately distingishable. Tributary deposits could also be quite different either in age, color, texture or all three.

Figure 3-1 illustrates a geomorphic setting and related stratigraphic units that would be pertinent to proposed channel improvements on a stream and some of its tributaries. Unit 1 consists of recent main stream deposits and unit 2 of recent deposits from the identified tributaries. These deposits constitute a replacement of older alluvium that was eroded during a lowering of base level in times past. Unit 3 consists of old alluvium which has undergone aging and the development of a profile. Unit 4 is a still older buried profile and unit 5 is an old stream terrace remnant.

Discontinuities in Alluvial Stratigraphic Units

Discontinuities are here defined as breaks in stratigraphic units that were originally continuous. Such breaks, narrow or wide, can have a bearing on the stability of an improved channel since the deposit may be replaced by more or less erodible material. Discontinuities can occur in a number of ways. One example is illustrated by Figure 3-1 where fine grained coherent soils developed at a higher base level than exists today. A lowering of this base level, created by a lowering of the nearby sea level elevation, caused downcutting of the main stream and then its tributaries. A subsequent raise in base level induced replacement by more recent sediments that are erodible.

Discontinuities similar to the above described type can occur without changes in base level. For example, a tributary producing a different type of sediment than the main stream can determine the characteristics of the deposit on the main floodplain in the vicinity of that tributary.

Occasionally the character of certain stratigraphic units differs widely from the type normally expected for a particular environment. For example, the occurrence of a very dark, highly coherent unit in a semiarid environment near the sea coast. In known instances where these disparities occurred, this coherent unit was interpreted to have accumulated during a rise in sea level. Fine sediment deposition in an embayment followed by the growth of marsh vegetation was probably the origin of this stratigraphic unit.

Another example of seeming disparity is the presence of an old fan of gravelly deposits encroaching on a valley but lacking a watershed of a size and geology capable of furnishing these materials. Inspection of geologic maps indicates that the gravelly fan deposits accumulated prior to stream piracy which transferred most of the watershed and also the source of coarse sediment to another drainage system.

Stratigraphic Units Without Internal Continuity

In certain geomorphic environments, the sediment deposited varies widely in texture within a short distance. If there is any unit identification, it is to the effect that there is a range in particle sizes from silt to gravel, all noncoherent, except for possibly some lens cementation. Such deposits are extensive in arid, semiarid and glaciated regions where in a network of ill-defined channels, the deposits were reworked during flood flows. Variability on a smaller scale may occur in humid climates where deposits accumulated during braided flows, but weathering and other factors contributing to development of coherent soil may be inhibited by such environmental factors as a high water table. In arid or semiarid climates, caliche by cementation can provide a resistant stratigraphic unit in an otherwise noncoherent alluvial deposit.

In the instances cited above, the absence of continuity, as well as the lack of coherence, should be established in the investigations stage preliminary to sampling. Then procedures to establish continuity can be modified.

Conducting the Site Investigation

Data Requirements and Observations Preliminary to Site Investigations

A longitudinal profile of the channel reaches to be improved, with survey stationing and profiles of the existing and proposed channel invert and top of bank is needed. A profile of the top of one bank is usually sufficient in alluvial valleys where the flood-plain surface is about the same on both sides of the channel. In addition, a flood-plain map is needed that shows the existing channel, the proposed channel, and the survey base line. The location of test sites and other pertinent geologic features are to be shown on the map.

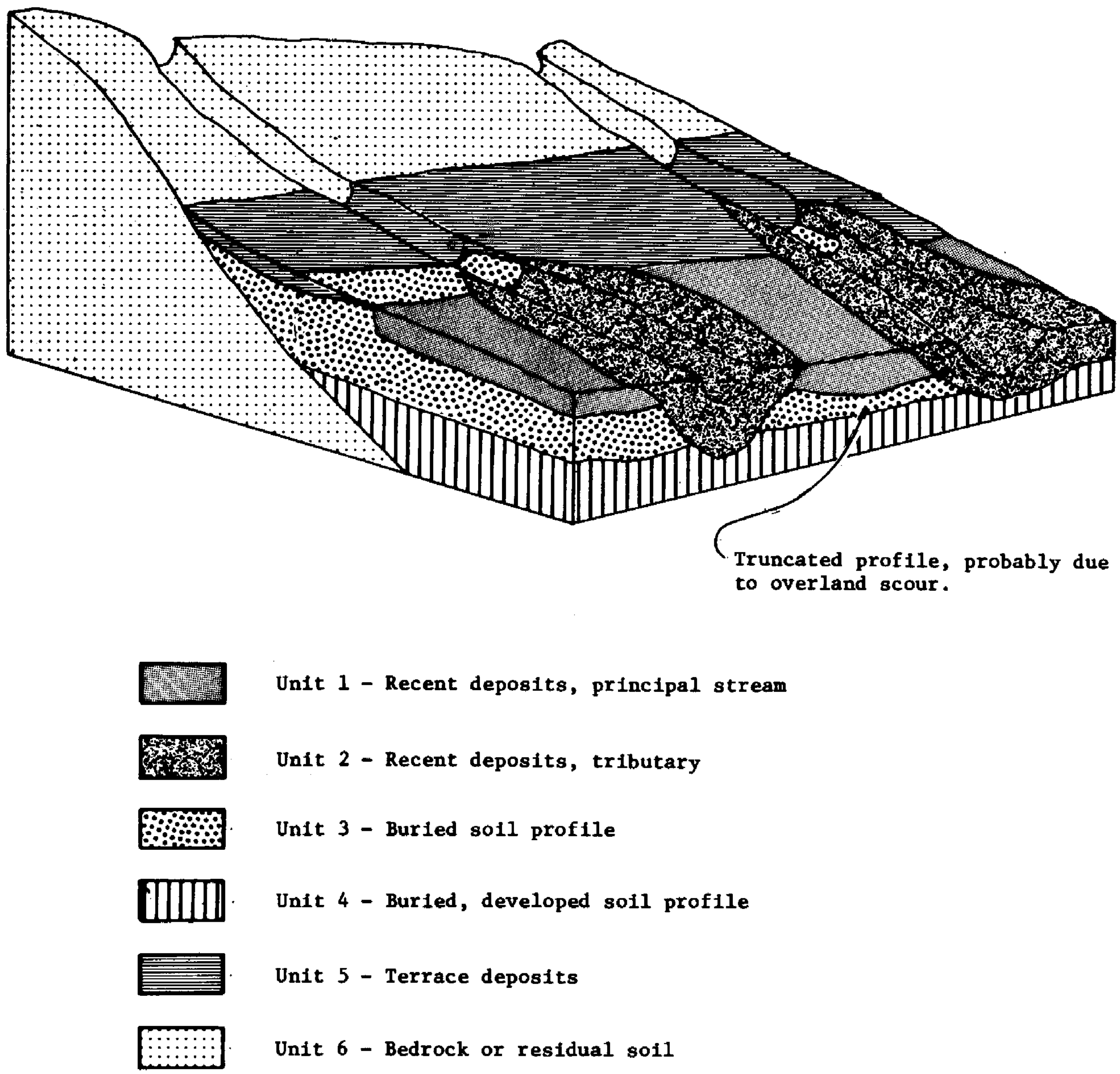

Figure 3-1 - STRATIGRAPHIC UNITS RELATED TO CHANNEL IMPROVEMENTS ALONG A STREAM AND ITS TRIBUTARIES (SIMPLIFIED)

Guidance on the erodibility of soils in a proposed channel improvement may be obtained by observation of existing channel performance. However, there should be a good general understanding of how flows will differ after project installation from what is characteristic under present conditions, that is, the change in grade, if any, the relative change in peak flows for frequent as well as infrequent events, and the relative change in duration of flows as well as frequency of bankfull flows. Observations on present stability are relevant if minor changes in flow characteristics are to be made. Such observations are substantially less relevant if major alterations in channelized flow are to result. These alterations could consist of on-site changes such as straightening and enlargement, or off-site changes such as upstream reservoirs that reduce the peak but substantially increase the duration of flows. For one example, an existing meandering channel is so small that overbank flooding may occur annually or more frequently. A proposed realigned and enlarged channel to be built to carry the ten percent event will cause a substantial increase in hydraulic stresses. The fact that existing stream banks are stable is not in itself supporting evidence that bank stability can be expected following construction. Then too, a major change in the rate of bed material load transport, if such load is present, can occur as a result of increased channel flow. While a general knowledge of changes in flow characteristics with project installed will suffice early in the field investigations, specific information will be needed in evaluating the erosion resistance of soils following sampling and laboratory analysis.

Bank sloughing or sliding may be a problem independent of changing discharge characteristics and needs to be identified. Fine sands, silts and some clays are susceptible to sloughing or slips under a range of moisture conditions. Sliding or sloughing may result from a rapid decline in water stage leaving a steep seepage gradient within the bank. The bank may slide or slough because of being undermined by erosion at the toe or by excavation below the water table. Underground flow from tributaries or springs, excessive rainfall, or over-irrigation can provide a source of ground-water flow which may result in bank sliding or sloughing. The location of any seeps or springs with reference to such problems should be identified.

Reconnaissance of Site for Channel Improvements

The initial field studies phase of site investigations should include inspection of the soils to and below the proposed channel invert level to interpret the geomorphology and to identify stratigraphic units. It is of primary importance to determine what stratigraphic units exist and their relationship one to another. This knowledge should be used to determine whether the same units occur at other randomly picked locations

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based on their appearance and lithology. Decisions on sampling sites, units to be sampled, and types of samples to be obtained must await their approximate delineation through the reach to be improved. Soil surveys along a proposed channel alignment can be useful in organizing the investigation and identifying stratigraphic units. It should be borne in mind that soil survey information is limited to a depth of about 5 feet and is frequently not reflective of stratigrahpic units at greater depth.

The inspection of the alluvial soil profile may be achieved by one or a combination of several means. Exposures along the banks of streams offer a frequently available means of study. This has the advantage of enabling observation of in-place characteristics as well as relating these characteristics to erosion from stream flow or bank stability from seepage forces. Bank stability may be due to protection by vegetation, or an irregular alignment which increases the roughness and thereby reduces the velocity or other reasons.

From the standpoint of bank stability from seepage forces, the existing channel could have sufficient vegetation, a protecting coating of fine sediment, or a ground-water level which has adapted to the channel depth over time. New excavation could cause problems which do not presently exist. Information gained from inspection of stream banks and bottom must be supplemented by borings or test pits when exposures along the banks do not provide sufficient information on the in-place characteristics of the deposits.

Exposed banks are often disturbed, desiccated or cracked and exhibit a different set of properties than the protected materials along the proposed cut and gradelines.

The place of observation along the channel is identified on the profile. Observation points in addition to those along the channel alignment will usually be required in order to interpret the stratigraphy and continuity of the valley deposits. The tentative upper and lower surfaces of stratigraphic units are determined and recorded on the profile. Each unit is to be numbered and geomorphically classified. For example, unit 1 is a recent sediment deposit overlying unit 2, a buried soil profile. Field notes and logs should describe the appearance and condition, including color, grain size, texture, structure, moisture, etc. of each unit in accordance with ASTM D-2488. Geomorphic terms are to be used in correlating between observation points. Identification as a stratigraphic unit is required in addition to the specific characteristics that can be described.

The tentative position of stratigraphic units within the profile and their extent along the channel alignment should form the basis for selecting soils investigation sites. The unit delineation must be informative enough to indicate the location of sites required to provide adequate data in the detailed investigation.

Determining the Intensity of Investigations

Four factors control the intensity of needed site investigations: (1) design requirements that may be independent or partially independent of the soil materials in the study reach; (2) hazard to life or property in the event of failure or partial failure; (3) complexity of the geomorphology in the site area; and (4) possible effects on quality of environment.

Concerning design requirements, for example, restrictions in availability of rights-of-way and capacity for each earth channel may dictate that the channel be a lined one, irrespective of the kind of materials in the reach involved. In this instance the investigations need only obtain the information that may affect construction such as classification of materials to invert grade, location of the water table and of seeps or springs. The presence of rock outcrops, layers of hard caliche, etc. should be carefully identified by location and description.

Where the water table is above proposed invert grade, its elevation should be identified in the logs of test holes or pits. If the water table fluctuates from season to season so that in one part of the year its elevation is below invert grade, the average time period this occurs and the dates of occurrence should be estimated. A high water table may interfere substantially with construction or affect the stability of an earth channel after excavation. If drop structures or other installations requiring data on bearing strength are being considered, investigations should be made in accord with recommendations in NEH, Section 8, Engineering Geology.

Channels located in urban or intensively developed agricultural areas differ widely in damage potential if a failure occurs than do channels in rural areas. In an urban area, the channel is usually designed to retain the one percent event with even minor erosion generally not tolerable. In both instances, the erosion characteristics of the bed and bank materials must be identified by procedures which include stratigraphic unit delineation and representative sampling and testing. Stratigraphic units must be more thoroughly delineated and variations within the units more closely identified by sampling and testing in intensively developed areas than in agricultural areas.

Complexity in the geomorphology of the site has a strong bearing on all phases of the investigation. Contrasting levels of complexity may include on the one hand a geomorphology as simple as one having a single stratigraphic unit uninterrupted by discontinuities, or maybe thin beds of sand or gravel that lack continuity and can be treated as one highly variable unit, to another that consists of a number of overlapping units frequently broken by discontinuities or disappearances from one reach to the next. In all instances, including those with the most complex array of stratigraphic units, an understanding is needed of the sedimentation processes and geologic history facilitates correlation and delineation of units, locations of discontinuities, etc.

The presence of dispersive clay soils along proposed channel alignment will have an effect on the intensity of investigation.

Dispersive clay soils often occur in lenses, spots and discontinuous strata. In order to tentatively identify dispersion problems, it will be necessary to check each stratigraphic unit at each test hole site for dispersive clays by means of the field "crumb" test performed on material at natural moisture. If field tests indicate possible dispersion problems, sufficient holes and samples should be established to delineate the problem areas or depths.

Location of Sites for Sampling and Logging

The location of pit or drill hole sites is based on the tentative delineation of stratigraphic units. There is a two-fold purpose in selection of these sites. One purpose is to obtain representative samples, the other is to "prove out" the tentatively identified stratigraphic units shown on the profile. If the logs at one test site fail to correlate with those at the site next upstream or downstream, then another site should be chosen between them, at least for the purpose of correcting the profile if not for additional sampling.

For long reaches where continuity of stratigraphic units has been established, it is best to sample widely from any one stratigraphic unit rather than concentrate in a small part of the total reach. This will improve the possibilities for discerning variations within the unit.

The usual location for test hole sites is on top of the bank near to but not necessarily immediately adjacent to the stream. The preliminary geomorphic determinations should indicate whether sites on both sides of the channel must be investigated.

In the process of investigation, the geologist should bear in mind that one part of a stream bank may be more subject to erosion than another due to differences in the hydraulic stresses that are exerted by the flow. These stresses are greatest on the bed, on the outside of bends, and along the toe of the banks. Greater emphasis in logging, sampling and testing should be used in searching for and identifying by thickness and location any easily erodible stratigraphic units from midbank to the invert level of the proposed channel. A bank is only as resistant as its weakest segment, particularly if this segment is low in the bank.

Determining the Sample Types to be Obtained

Prior to the detailed investigations, the geologist and engineer have made a tentative decision as to whether data from undisturbed and disturbed samples are to be obtained and the best means for obtaining them. Each stratigraphic unit observed in an undisturbed condition is evaluated before the decision is made as to the type of sampling to be done. It is a good rule to obtain undisturbed samples when in doubt as to whether the unit is characteristically composed of discrete particles or of aggregates that would resist erosion as a mass. The effects of the environment on sediment, once it has accumulated, is discussed in the section on the geomorphology of alluvial deposits. The in-place behavior of materials that resist erosion as a coherent mass cannot be determined by testing disturbed samples. Hence, undisturbed sample analysis is critically important if the in-place deposits differ in erodibility from that of the individual particles. The Unified Soil Classification System and similar systems do not identify erosion characteristics of an undisturbed coherent soil mass except that soils with a high plasticity index (P.I.) are usually more resistant to erosion than noncoherent soils. Some undisturbed soils with a low P.I. are about as resistant to erosion as those with high P.I., and under certain conditions, material with a high P.I. can be as erodible as one with a low P.I. such as soils that are highly dispersive. Another such condition exists when the soil mass is weakened by a fine network of fractures such as that which may be caused by expansive clays. The fractures may or may not be filled with dissimilar material. The above would have to be determined by appropriate tests and observations.

Careful selection of investigation tools and procedures for investigations are necessary to obtain samples and logs of the natural, undisturbed in-place materials. Augers, excavation equipment and many laboratory procedures disturb the soils and provide data which result in erroneous interpretations of in-place properties.

Selection of Equipment for Logging and Sampling

The frequently limited depth required in field investigations for channel improvements and the advantages afforded by in-place examination of the alluvial profile indicates that at least a framework of pit excavations is desirable. Safety precautions must be rigidly maintained. The backhoe is the preferred equipment for such excavations. Once in-place profiles can be examined and sampled above water tables, the pits can be supplemented by drill holes below water tables. Limitations of pits include the possibilities that the depth of sampling required exceeds the capabilities of available equipment, that a high water table would restrict or prevent investigations below that level, and that access is sometimes limited for physical reasons or property owner objections. The advantages of drilling equipment are no depth or ground-water limitations, in-place testing with less site disturbance, and greater safety. For guidance in maintaining safe working conditions, refer to the safety manual for geologic investigations. Light weight drilling equipment mounted on track vehicles may provide a means of collecting disturbed and undisturbed samples from areas that are not accessible to heavy drill rigs.

Sampling equipment is described in NEH, Section 8, Chapter 2. In instances where drilling equipment is used, push tube sampling of relatively soft fine-grained soils or Denison core barrel sampling of hard fine-grained soils are recommended. Special equipment has been devised for undisturbed sampling of soils in investigations for channel improvements where pits or stream banks are the sampling sites. Figure 3-2 is a drawing of the sampling tool which is designed for placement on a shelf dug in the side or bottom of a pit or bank. It is built to obtain more than one sample from the same setup. The thin-walled brass tubes used should be at least two inches and preferably larger in diameter by five or six inches in length. This size is usually sufficient for shear strength tests. Duplicates from the same stratum must be obtained in the event one is damaged in shipping or handling. Following tests in an undisturbed condition, the same material is used for classification, or an additional sample of the disturbed soil can be obtained. The sample or samples are judged to be undisturbed if the soil column on the inside of the tube and on the outside are both level with the upper edge. A tendency for compaction to occur in a tough, dry soil because of the frictional resistance can be reduced by pre-wetting the inside of the tube with water or a small amount of a light lubricant. On completion of sampling, the tubes are sealed. It is essential that the undisturbed samples do not become desiccated.

The cutting of cubes or other block shapes for laboratory testing is another means of obtaining undisturbed samples. It may, in fact, be necessary to obtain such samples if other equipment compacts or otherwise

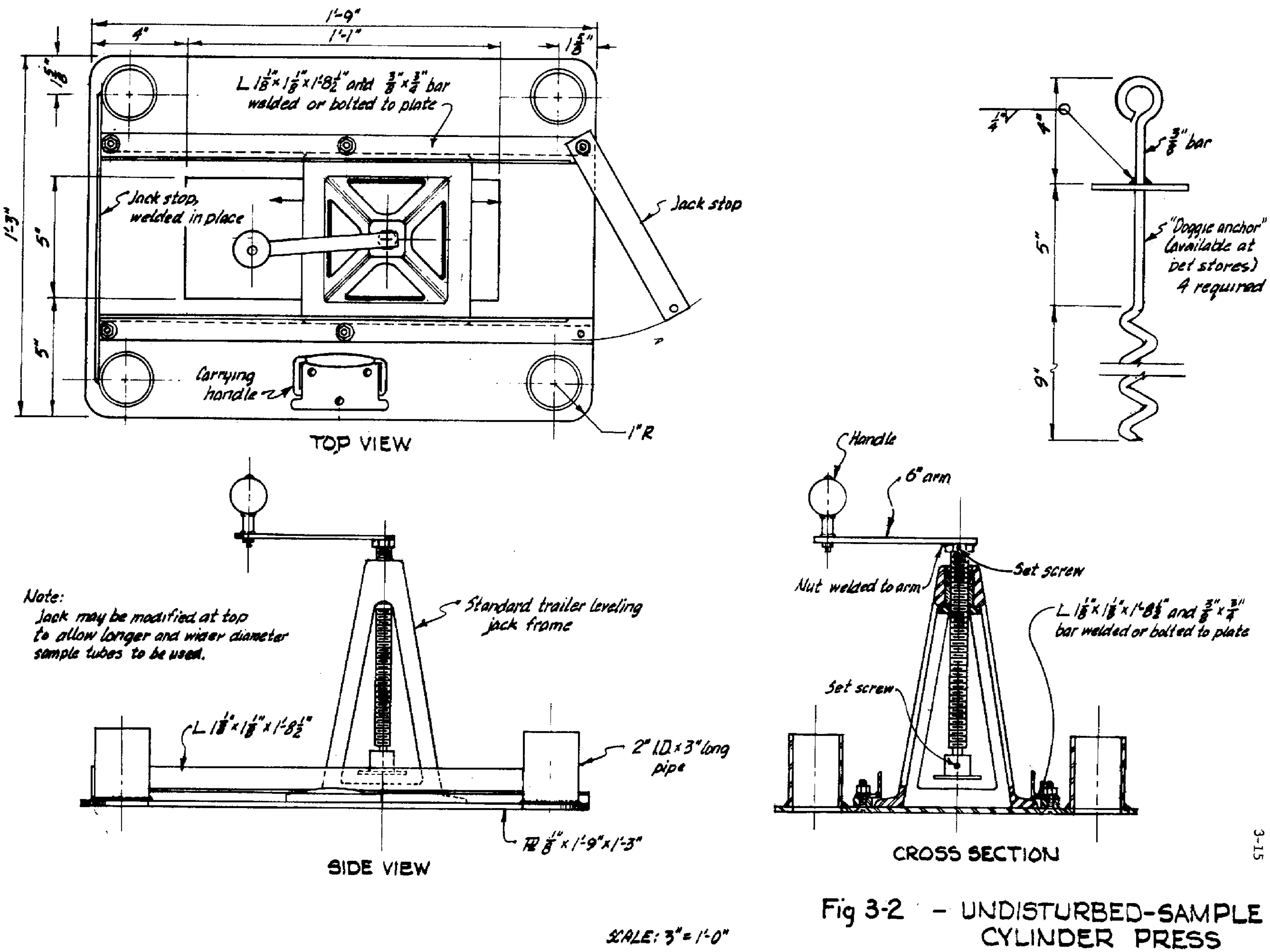

Fig 3-2 - UNDISTURBED-SAMPLE CYLINDER PRESS

disturbs the soil. While this sampling procedure is usually much more time consuming than push tube methods, it generally results in a much better sample. The presence of coarse sand or gravel in the soil can render the push tube or drill hole sampling equipment unsuitable for use in obtaining undisturbed samples. Exposures in stream banks or pits sometimes exhibit pockets of fine-grained matrix free of the coarse particles. These pockets frequently contain the same material and the same erosion resistance properties as the matrix in an intimate mixture of coarse and fine particles. Sampling and testing of this fine-grained matrix can provide information on the erosion resistance of the mass. Careful evaluation is necessary to insure the applicability of such data.

Channel improvements may include the construction of dikes or embankments to protect adjacent lands from overflow or to increase the resistance of natural materials by compaction. The sample needs for these construction purposes as well as for foundations for all structures should be discussed with the engineer prior to the detailed site investigations. The amounts of disturbed samples needed for various tests and sizes of material are described in Tables 3-3 and 3-4. Packaging and shipping instructions are given in NEH, Section 8, Chapter 3, pages 10 and 11.

Test Hole Logs

Logs of test holes should contain necessary information to ensure that the stratigraphic units are identified and their characteristics, depth of occurrence in the hole and thickness are recorded. If a stratigraphic unit identified in the adjacent test hole fails to appear in this one, this information should be noted. Figure 3-3 is a suggested field worksheet for logging and sampling at test hole sites.

Generally bedrock will not be drilled during investigations. Descriptions of bedrock characteristics are to be provided for the engineer's use. These descriptions must be thorough, complete and accurate.

Determination of the Availability of Movable Bed Material

The availability of movable bed material, specifically sand and gravel, must be determined in order to evaluate its impact on the stability of the improved channel. The most apparent source of supply is deposits that may have accumulated in the bed of the stream within and above the reach to be improved. Whether or not the bed-material supply is a threat to the operation or reasonable maintenance of the improved channel depends on several factors. These include the amount and ease of transport of the material and the difference in hydraulic characteristics between the reach to be improved and the reach upstream that contains the bed material. The relationship between bed material availability and channel stability is discussed in NEH, Section 3, Chapter 4, Transportation of Sediment by Water, pages 4-36 and 4-37.

The channel investigation should include an estimate of the volume of bed material available in the bed of the stream and where the deposit is located with reference to the proposed improvement. If the bottom of the deposit cannot be reached, this should be indicated in the notes. Representative samples of the bed material are to be obtained. The amount required for various gradations of material is given in Table 3-2, NEH, Section 8, Chapter 3. A sample of the surface armor should be obtained, if present, as well as a sample of the underlying finer accumulation.

For analysis of stability, the geologist is expected to define whether discharges critical for stability should be defined as "clear water" or sediment laden flows. In most instances, the wash load will not be of sufficient concentration to classify the flows as other than "clear water". An examination of suspended load records on a regional basis will provide good clues as to the likelihood of significant concentrations. A knowledge of the watershed will also serve to indicate the extent of critical erosion. Reservoirs will reduce concentrations to relatively low levels.

The influence of bed material on the stability of channels is discussed in NEH, Section 3, Chapter 4, pages 4-25 to 4-28.

Where bedrock is to be removed from the channel, the potential effects on stream banks and bed both upstream and downstream must be considered. Where rock is to be removed from a channel section, its disposal must be planned. Alternative disposal methods may include wasting in a preselected area, use in channel construction (riprap, filters), salvage, etc. Local highway agencies are often valuable sources of information concerning rock quality and ease of removal.

Site Investigation Reports

Completion of the Stratigraphic-Unit Profiles

The first step in preparation of site investigation reports is to complete the longitudinal profile and description of stratigraphic units in the channel reach to be improved. As stated on page 3-11, this is

Sheet ____ of ____
Date ____________

WORK SHEET
FOR
LOGGING AND SAMPLING DATA-GEOLOGIC INVESTIGATIONS FOR CHANNEL IMPROVEMENT

Watershed *Cottonwood* Stream *Cottonwood Creek* County *Jones* State *Any*

Site location by survey stationing *65+60* Investigation site number *8* Method of investigation *backhoe*

Log of Unit

Depth *(ft)* From	To	
0	*3*	STRATIGRAPHIC UNIT NO. *1*
		Description: *A recent deposit of dry, firm, homogeneous, light brown silt (ML), low in organic*
		matter. The deposit breaks down easily into discrete particles and is identified in the field
		as noncoherent. This is the same stratigraphic unit as at investigation site 7, from 0-3.5 ft.
3.0	*6.5*	STRATIGRAPHIC UNIT NO. *3*
		Description: *A dark grey, moist, firm, homogeneous silty clay (CL) relatively free of jointing,*
		roots or other factors that may affect erosion. The unit is identified in the field as coherent.
6.5	*8.0*	*Contains yellow mottling indicative of poor drainage conditions. This stratigraphic unit*
		(3.0 to 8.0 ft.) was identified between 3.5 and 7.5 ft. at site 7. Water table at 7.0 ft.
		STRATIGRAPHIC UNIT NO. ____
		Description:

Figure 3-3

to be developed in tentative form during the preliminary investigation of the site. With the benefit of the additional information obtained during logging and sampling, the original profile is to be refined to include more precise information on the extent, thickness and position in the profile of stratigraphic units. The survey stationing, bank line, and proposed invert level are to be plotted, as are the locations and logs of pits or drill holes. The upper and lower elevations of stratigraphic units will be shown at the appropriate station site. When the correlation of units between pit or drill hole sites has been determined, correlation lines are drawn as shown on Figure 3-4. In this example, it is implied that correlation between test hole sites has been facilitated by exposures in stream banks. Additional test holes would be required where such exposures are not available.

The "U" on the right of the profile test hole location indicates that an undisturbed sample was obtained. A disturbed sample may or may not be obtained at the same site depending upon whether enough material is available in the undisturbed sample for classification. The investigators have identified this stratigraphic unit as consisting of soil which would resist erosion as a mass rather than as discrete particles. The "D" indicates that a disturbed sample has been obtained. The investigators have made a field determination that the unit is non-coherent and that erosion characteristics are dependent on the individual particle characteristics. The stratigraphic unit delineations on Figure 3-4 are not dependent on the indicated investigation sites alone but include determinations from observations along stream banks and from hand borings. When the test data have been obtained, results pertinent to the erosion or stability characteristics may be shown or listed on attached report sheets with the data clearly identified with the appropriate units. Ground water, if encountered, should be shown at each of the investigation test hole locations.

The longitudinal profile with stratigraphic unit interpretations is primarily for purposes of stability evaluation, and without it the designer does not know that interpretations of soil characteristics have been made between investigation sites.

The logs of test pits or drill holes and the plan map showing the location of these investigation sites should accompany the profiles as supporting and supplemental information and a copy will be placed in the design folio.

The geologic profile and plan map should show the locations and the extent of outcropping bedrock. They should also show its verified or estimated depth below the present streambed and its relation to the proposed channel invert. Existing erosion or deposition features associated with the outcrop (either up or down stream) should also be shown.

Analysis of Channel Stability

With the longitudinal profiles, logs and laboratory test data available, the geologist and engineer are in a position to make an analysis of the stability of the proposed channel improvement. In addition, information is needed on the design discharge if bed-material load is not involved as a problem, and the hydrographs for design as well as more frequent discharges if bed-material load has been determined as a problem. Chapter 6 of this Technical Release or designated supplements are to be used for determining the stability of channels that are not affected by bed material transport. NEH, Section 3, Chapter 4, is to be used for the analysis of bed-material transport that may affect channel stability.

Report Outline and Documentation

The longitudinal profile, the plan view, logs, field and laboratory test results, and stability analysis are to form the documentation for a brief report based upon the following outline. Geologists and engineers are both involved in an analysis of these problems. They should work closely together in the determinations and report preparation.

A. Conclusions and Recommendations

B. Description of the geomorphology of the channel improvement area

   Basis for stratigraphic unit delineation with reference to longitudinal profiles or reasons for lack of stratigraphic unit delineation.

C. Copies of logs and test data

D. Criteria used to establish stability

   1. Condition of flow to be used in stability analysis: clear or sediment-laden water. Basis for criteria used.

   2. Bed material evaluation procedure used among those recommended in NEH, Section 3, Chapter 4.

E. Stability analysis

   1. Stability under proposed as-built conditions

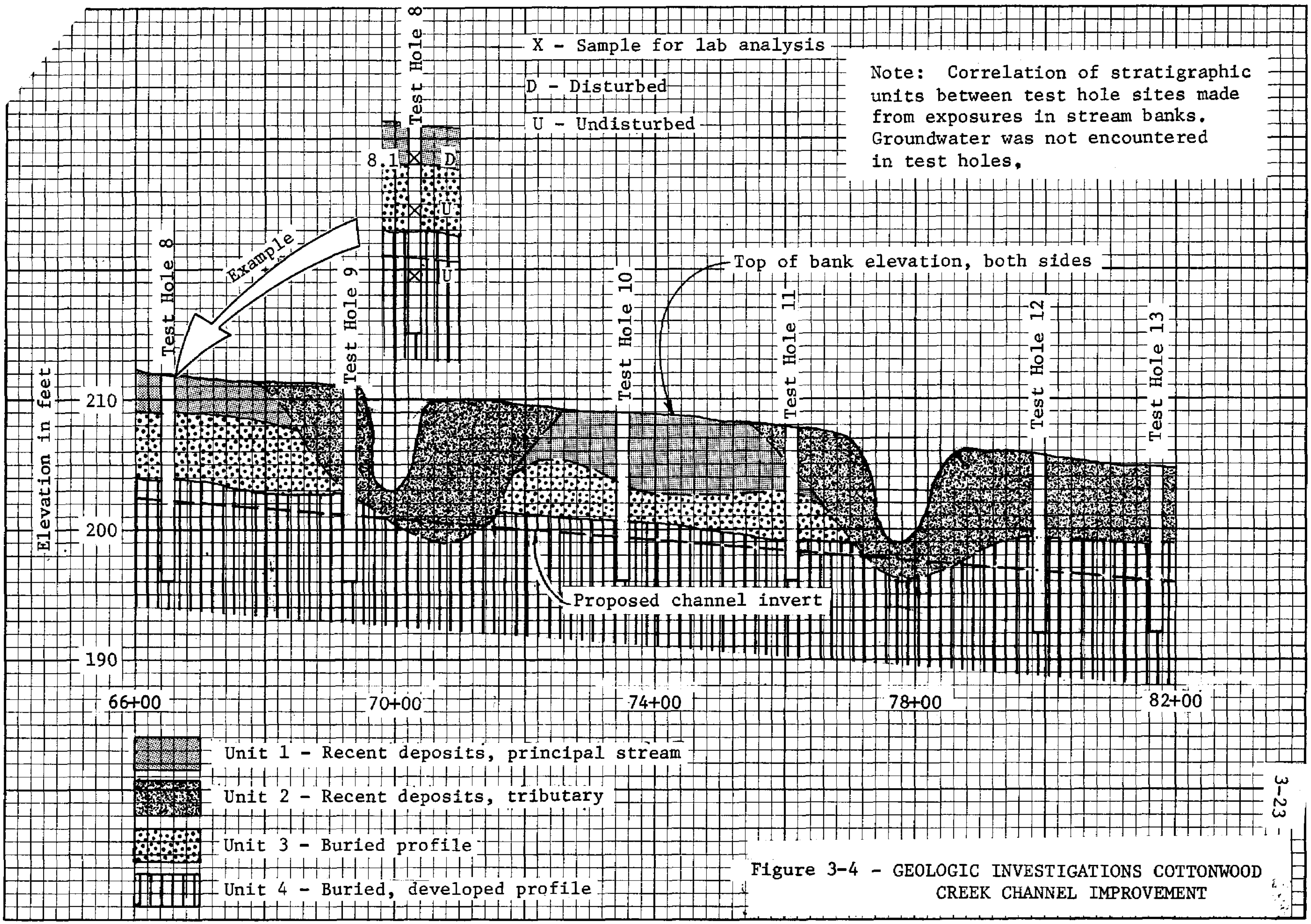

Figure 3-4 - GEOLOGIC INVESTIGATIONS COTTONWOOD CREEK CHANNEL IMPROVEMENT

a. Location of projected unstable reaches, if unprotected; bed and/or banks by stationing.

   (1) Elevation of unit or units with reference to invert level.

   (2) Cause of predicted conditions, such as tractive stress or velocity in excess of allowable or internal seepage forces.

b. Discuss unique conditions not fitting into the assumptions made in Technical Release 25.

2. Bed material sediment problems if these influence stability of proposed channel improvements.

3. Effect of program installations, such as floodwater, floodwater detention or multipurpose structures, debris basins and grade control structures on downstream reaches.

Evaluation in the Construction Stage

Unexpected discontinuities or unaccounted variations in soil characteristics affecting stability may be revealed during excavations for improvements. It should be standard procedure for the geologist, design engineer and soils engineer to examine the channel during or immediately after excavation. With the profiles at hand, the geologist should make any pertinent adjustments in unit delineation and interpretations over those prepared during the design investigations. Any significant alterations pertaining to stability should be immediately called to the attention of the project and construction engineers.

Testing

Purposes of Testing

The purposes of testing soils from channel projects are fourfold:

1. To develop design values and correlation between properties of fine-grained soils and field evaluation and classification of erosional activity in constructed or natural channels now in use.

2. To provide values for use in the design of stable channels in gravels and coarse sands from the standpoint of erosional activity.

3. To provide values for the design of channel banks from the standpoint of shear strength and sliding.

4. To evaluate earth loads on structural members.

Test Procedures

Tests may be conducted in the field and/or in the laboratory. Testing procedures should conform to standards of the American Society for Testing Materials (ASTM) or American Association of State Highway Officials (AASHO).

Types of Tests

Two categories of tests are presented---primary tests and supplementary tests. Primary tests are those that provide values that may be used directly (1) to evaluate erosion by either the tractive force, limiting velocity, or tractive power procedures discussed in Chapter 6, or (2) to analyze bank slope stability problems discussed in Chapter 6. Supplementary tests are those that will provide supporting or indicator information that may be of assistance in evaluating erosional resistance and bank stability. These latter tests may be made at local option; results from these tests are not needed to use the design criteria set forth in this Guide, but they may provide valuable clues to the designer.

Index and engineering properties tests are listed in Table 3-1 for erosional analyses and in Table 3-2 for bank stability analyses. Field tests that may be used where conditions warrant are discussed in NEH, Section 8, Chapter 1.

Classification. - - Soils should be fully described and classified according to the Unified Soil Classification System (ASTM D-2488).

Particle size distribution. - - A mechanical analysis should be made on selected samples representing soils that are or may be exposed to erosional forces in channel bottoms and banks to determine the distribution of particle sizes. The coarse fraction should be analyzed using the following U. S. Standard Sieves as the minimum number of size separations: No. 200, 140, 40, 20, 10, 4 and 3/8", 3/4", 1 1/2", and 3". Other size separations may be introduced if considered necessary. The fine fraction should be analyzed using the standard hydrometer tests. Results should be reported on the basis of total material.

Soil consistency tests. - - The liquid limit, plastic limit, and plasticity index should be determined for all soils, except clean sands and gravels, in order to differentiate between materials of appreciable plasticity and slightly plastic or non-plastic materials.

Table 3-1

Erosional Analyses

A. Index Tests

1. Classification 1/

   a. Mechanical analysis

   b. Liquid limit

   Plasticity index

   c. Plastic limit

2. Dispersion

   a. Field tests to identify possible problem areas

   b. Lab tests for soils with more than 15% >.005 mm and for a P.I. >8

3. Soluble salts

4. Natural dry unit weight

B. Engineering Properties Tests 2/

1. Permeability

2. Shear strength

   a. Unconfined compression 3/

   b. Vane shear

1/ For tractive force, limiting velocity or tractive power procedures.

2/ These tests may be made at local option. Results will provide supporting information which may assist in evaluating erosional stability.

3/ For tractive power procedure only.

Table 3-2

Bank Slope Stability Analyses

A. Index Tests

1. Classification

a. Mechanical analysis

b. Liquid limit

Plasticity index

c. Plastic limit

2. Specific gravity

a. Particles smaller than No. 4 sieve

b. Particles larger than No. 4 sieve

3. Natural dry unit weight and natural moisture content

4. Compaction

B. Engineering Properties Tests

1. Shear

a. Unconfined Compression

b. Direct

c. Triaxial

d. Vane

2. Permeability

C. Other Tests 1/

1. Dispersion

2. Soluble salts

3. Linear shrinkage

1/ These tests may be made at local option. Results will provide supporting information which may assist in evaluating bank stability.

Specific gravity. - - When soils are composed of particles having 95 percent or more (by dry weight) smaller than the No. 4 sieve (4.76 mm.) and when compaction or shear tests are required, specific gravity tests should be performed on the minus No. 4 fraction.

When soils contain five percent or more (by dry weight) of hard particles larger than the No. 4 sieve and when compaction or shear tests are required, absorption and bulk specific gravity (saturated, surface dry) tests should be performed on the coarse materials as well as on the fraction smaller than the No. 4 sieve.

Results of specific gravity tests are needed for computation of porosity, void ratio, and associated air-water-solid relationships; also results are needed for adjustment of moisture-density relationships for compacted materials having five percent or more larger than the No. 4 sieve (by dry weight).

Strength considerations. - - Some measure of inter-particle attraction may prove helpful in evaluating erosional stability of channels on the basis of the tractive force theory. Although shear strength obtained by various tests has been used by some investigators, it may not be a true indicator of inter-particle attraction.

Strength values for use in slope stability analyses of banks should be governed by site conditions and the method of analysis to be used. Therefore, some latitude is needed by the engineer in the selection of appropriate tests to be performed at a given site for determination of shear strength parameters.

1. Unconfined compression test. This test is commonly called a q_u test and may be performed on saturated, undisturbed specimens. The test may be made for two purposes: (1) to obtain unconfined compressive strength values for use in estimating erosional stability (by the tractive power method) of those soils in which individual particles cohere under natural field conditions, and (2) to obtain values of cohesion (no load strength) for use in analyzing the stability of banks from a strength standpoint. In the latter case, the test is generally applicable to highly plastic soils, but it may be used for other soils where the in-place strength will simulate ultimate field conditions.

   The q_u test should not be performed on those soils in which natural planes of weakness are an inherent characteristic of the soil, as exemplified by stiff, fissured clay or soils having blocky or columnar structural development.

The effects of weathering should be considered in using q_u test results from samples taken at a depth which will later be unloaded and exposed to the atmosphere -- both in an erosional evaluation and in a bank stability analysis. This consideration will be a matter of judgment and local experience.

2. Direct shear tests. Drained, direct shear tests are recommended for determining the strength parameters for use in the analysis of banks against sliding when the effect of pore water pressure is included as a separate item. Cohesive and non-cohesive soils may be tested in this manner.

3. Triaxial shear tests. Consolidated, undrained, triaxial shear tests may be used, but will generally not be required, for strength parameters unless fractured or structurally cleaved soils are involved.

   Consolidated, undrained, triaxial tests may be made without pore pressure measurements when pore pressures which are anticipated in the field can be simulated during testing.

   When triaxial shear tests are used instead of direct shear tests and when pore pressures are considered separately in the stability analysis, it will be necessary to perform consolidated, drained tests or to perform consolidated, undrained tests with pore pressure measurements.

4. Vane shear tests. The vane shear test is a field test which is well adapted to obtaining in-place shear strength of saturated, plastic soils that do not contain gravel. Shear strength values obtained by vane shear tests may be used for bank stability analyses. This type of test is especially applicable when soils are sensitive and when it is difficult to secure and transport undisturbed samples. Vane tests should include results on remolded strength as well as peak strength.

Natural dry unit weight and moisture content. - - The natural dry unit weight and natural moisture content should be recorded for all undisturbed samples. These determinations can be made in conjunction with shear test operations. Proper interpretations of shear test results are dependent upon data on variations in natural dry unit weight and moisture content.

The erosional resistance of many soils, particularly those which are weakly coherent, increases as dry unit weight (density) increases. The natural (in-place) dry unit weight of soils exposed in the channel will provide valuable guidance in the review and evaluation of the performance of existing channels functioning under similar conditions to a planned channel.

Compaction (moisture-density relationship). - - The moisture-density relationship of soils (for a given compactive effort) should be known before shear testing of disturbed (borrow) materials can be instigated or before field control of moisture and density can be maintained. Compaction and field control may be necessary either (1) to assure adequate density and shear strength in levee or dike fills or (2) to increase the erosional resistance of low density, weakly coherent soils which form the bottoms and sides of channels.

Compaction tests should be performed on disturbed samples of selected representative soils on which shear tests are required for design and/or field control of moisture and density are required during construction operations. Compaction tests are also used to evaluate collapse potential of soils. Most highly collapsible soils are also generally highly erosive.

Permeability. - - In those cases where seepage from channel banks may be a problem, the permeability of natural materials may be required to construct flow nets and to analyze seepage forces. Permeability tests should be performed on undisturbed materials which are representative of soils in the problem area.

Field permeability tests will usually be the most effective means of determining permeability rates (a) in non-coherent soils which are difficult to sample representatively, handle and transport to the laboratory and (b) in lenticular and highly stratified soils.

Methods of making field permeability tests are described in NEH, Section 8[5/], Chapter 2; Section 16[2/], Chapter 2; Special Publication SP-SW-0262 of the American Society of Agricultural Engineers[7/]; and the Earth Manual, First Edition, U. S. Bureau of Reclamation[8/].

A permeability test may also be performed as a secondary and companion test to the unconfined compression test when the purpose of the latter is to provide values for use in an erosional analyses of coherent or cemented soils[9/] (see Chapter 6). The permeability test described hereafter is not necessary when the unconfined compression test is made for the purpose of providing values for a bank stability analysis.

A permeability test, as a companion test to the unconfined compression test, should be performed in a falling head permeameter on undisturbed specimens having a ratio of height to diameter equal to approximately two. As soon as consistent head readings are obtained, the test should be discontinued; the specimen should be removed from the permeameter immediately and subjected to an unconfined compression test to determine the coherence of the saturated specimen.

Dispersion. - - The terms dispersive clay or dispersion refer to the stability of soil aggregates when exposed to water. Dispersive soils are highly erosive. When dispersed soils are exposed to weathering, they are easily distinguished by field observation. They tend to melt down like sugar, develop land forms that resemble typical "badland" relief (macro or micro) and form "slick spots" that are generally bare of vegetation.

There are several tests that identify dispersive soils.

1. The field "crumb" test identifies dispersive soils by the formation of a colloidal cloud around a small clod of moist soil dropped into distilled water or very dilute sodium hydroxide.

2. The laboratory dispersion test identifies most dispersive soils by comparing the amount of 0.005 mm. material in a suspension without deflocculating chemicals to the total amount of 0.005 mm. material determined by mechanical analysis.

3. The field dispersion test is an abbreviated version of the laboratory dispersion test.

4. Chemical tests identify dispersive soils by comparing the amount of soluble sodium and the total salt content in the saturation extract or pore fluid of the soil.

None of these tests <u>always</u> correlates with the others or with field performance. It is sometimes necessary to run all tests in order to properly evaluate the adverse effects of dispersive soils.

Whenever dispersion is suspected in an area, laboratory tests should be run to verify and evaluate the problem.

Soluble salts. - - Soils that contain considerable soluble salts, particularly gypsum, are highly erodible and may slough badly. It appears that the recrystallization of gypsum and other salts during sedimentation results in an open, honeycombed soil structure that may be compared to loessial materials. These soils have sufficient stability to stand on vertical banks as long as they are dry, but they slough and erode rapidly when exposed to moisture. Sodium salts have a dispersive effect on soils and generally increase the erodibility of soils. Although high soluble salt content in soils tend to keep the soil in a flocculated or aggregated (erosion resistant) state, these salts would generally be removed or leached back into channel banks during high flows, possibly leaving a deflocculated, dispersed, erodible surface layer. In arid and semi-arid regions, the soluble salt content may be determined for representative samples, even though results of this test cannot be used quantitatively at present.

Linear shrinkage. - - Coherent soils which have linear shrinkage factors in the range of ten percent or more are generally subject to considerable density and strength changes with variations in moisture content. Results from linear shrinkage tests on coherent soils serve as indicators of potential problems related to bank stability.

Field Sample and Test Specimen Requirements

The quantity of materials needed for testing depends primarily on such factors as (1) number, type and purpose of tests to be performed, (2) particle size characteristics of the material, and (3) homogeneity of the natural materials, particularly when undisturbed specimens are to be tested. The minimum number of test specimens for one test is given below:

Unconfined compression	1
Direct shear	3
Triaxial shear	3
Permeability	1

It is suggested that undisturbed samples be large enough so that an additional test specimen will be available as a spare. In the case of small diameter tube samples, duplicate sampling should be obtained.

Sample sizes and specimen requirements for testing of soils from channel projects are given in Table 3-3 (Disturbed Samples) and 3-4 (Undisturbed Samples). The specimen sizes given in Table 3-4 are those which are actually required for testing; these sizes do not include allowances for trimming.

Table 3-3

Minimum Size of Disturbed Samples

Required for Testing Purposes

Test	Maximum Size to be Included in Samples	Gradation Characteristics of Natural Material		
		90-100% Passing #4 Sieve	50-90% Passing #4 Sieve	0-50% Passing #4 Sieve
Mechanical analysis, liquid limit, plastic limit, specific gravity, dispersion, soluble salts, linear shrinkage	3 in.	4 lb.	10 lb. 1/	40 lb. 1/
Compaction and shear	3 in.	25 lb.	40 lb. natural material	2/

1/ Provide estimates of the percent of oversized material (plus 3 inch size) excluded from samples shipped to laboratory.

2/ Forty pounds of these materials will be adequate for all applicable tests.

Table 3-4

Minimum Specimen Requirements (After Trimming) for Testing Undisturbed Samples

Maximum Particle Size	Test 1/	Size of Specimen
No. 4 sieve (4.76 mm.) 2/	Unconfined compression	1.4" dia. x 3" long
	Direct shear	2.0" x 2.0" x 1" thick
	Triaxial shear	1.4" dia. x 3" long
	Permeability	2" dia.
1/2 inch 2/	Unconfined compression	2.8" dia. x 6.0" long
	Triaxial shear	2.8" dia. x 6.0" long
	Permeability	4.0" dia.
1 inch 2/	Triaxial shear	4.0" dia. x 8.0" long
	Permeability	6.0" dia.
1 1/2 inches	Triaxial shear	6.0" dia. x 12.0" long
	Permeability	6.0" dia.

1/ Table 3-3 gives the sizes of materials which are required for mechanical analysis, liquid limit, plastic limit, specific gravity, dispersion, soluble salts and linear shrinkage. If undisturbed samples are not large enough to meet these requirements, disturbed samples of the sizes indicated should be taken at the same elevation from an adjacent hole to represent the undisturbed materials.

2/ If materials have scattered particles larger than the sizes shown, it may still be possible to trim these test specimens without going to a larger specimen size.

Appendix to Chapter 3

OUTLINE TO PLAN SITE INVESTIGATIONS AND PREPARE REPORTS FOR CHANNEL IMPROVEMENTS

I. Introduction

A. Investigational considerations

1. Channel improvements may be many miles in length.
2. Depths to channel bottom are shallow, usually less than 20 feet.
3. Correlation is necessary to predict presence of boundary materials between holes to avoid inadequate design.
4. An understanding of the geomorphology of alluvial deposits and the identification of stratigraphic units at each site are necessary for correlation of deposits with similar erodibility.

B. Definition of a stratigraphic unit

A stratigraphic unit is defined in this instance as an identifiable stratum of alluvium or other soil material whose susceptibility to erosion is a reflection of the original materials, mode of accumulation and the changes that have occurred since deposition or soil formation.

II. Geomorphology of deposits

A. Significance of the stratigraphic unit and factors that affect the characteristics and erodibility or resistance of stratigraphic units.

1. The characteristics of the original deposits.
2. Age of the deposit.
3. The environment since deposition.

B. Identification of stratigraphic units

1. Primary identifying characteristics are color, particle size, particle size distribution, plasticity, cementation, density, dispersion, structure, and thickness.
2. A stratigraphic unit occupies the same position relative to other beds in a sequence.
3. A stratigraphic unit usually occupies the same position across the valley as it does near the present channel.

C. Geomorphic history determines the erosion resistance of stratigraphic units

1. The particle size distribution and texture of the deposit are the primary determinants of erosion resistance initially.
2. Changes in the character of the material occur with time such as:
   a. The movement downward of fine particles.
   b. Weathering.
   c. Consolidation by overburden, alternate wetting and drying, desiccation, etc.
   d. Cementation.
   e. The accumulation of humus.
3. The geomorphic history results in a characteristic erosion resistance for each stratigraphic unit.
4. The unit may consist of individual particles without connecting bonds.

a. A grain size (as D_{50}, D_{65}, D_{75}) is the quantitative identifier of erosion resistance.

b. Disturbance does not affect the erosion resistance.

5. The unit may consist of particles that cohere or that do have a connecting bond.

a. The degree of coherence is strongly affected by the geomorphic history.

b. Disturbance destroys some of the affects of geomorphic history on the unit's erosion resistance.

D. Discontinuities in stratigraphic units

1. The stratigraphic unit may completely disappear from one test hole site to another. This is identified as a discontinuity.

2. The stratigraphic unit may be interrupted by erosion and replaced by different materials. This is also identified as a discontinuity.

3. The stratigraphic unit may locally thin or thicken. This is a variation within a continuous unit, <u>not</u> a discontinuity.

E. Stratigraphic units without internal continuity

1. Some stratigraphic units vary widely in grain size and other characteristics within a short distance.

2. Such variations cannot be correlated between one test hole and another.

3. Such units are identified as lacking internal continuity.

III. Data requirements and observations preliminary to site investigation

A. Data requirements prior to investigations

1. Longitudinal profile of channel reaches to be improved and includes:

   Survey stationing and profiles of existing and proposed channel invert (bottom) and top of bank

2. Flood plain map to include:

   a. Existing channel.

   b. Proposed channel.

   c. Survey base line.

3. When to evaluate stability of existing channels prior to field investigations.

   a. Capacity, slope, frequency at bank full, and other hydraulic measurements are similar to proposed improvement.

   b. Channel boundary soils are exposed to hydraulic forces.

   c. Stability of channel under specified flood discharges and frequencies can be identified.

   d. Water table fluctuations affect bank stability.

B. Reconnaissance of site for channel modifications

1. Inspect soils to and below proposed channel invert level. Study exposures along stream banks and in stream bed. Supplement by test pits or borings where necessary.

2. Interpret geomorphology, tentatively identify stratigraphic units. Geologic, soil survey and topographic maps are very useful for study preliminary to the investigation.

3. Identify places of observation on longitudinal profile.
4. Prepare tentative stratigraphic unit delineation on profile from observations made above.

IV. Site investigations

A. Determine the nature and intensity of site investigations.

Factors that affect the intensity of site investigations:

1. Site limitations may require channel lining independent of soil characteristics. Investigations limited to determination of site preparation and construction problems.
2. A potential high hazard to life and property can require a closer spacing of test holes, more intensive soil sampling and testing than a low hazard site.
3. A complex geomorphology will require a closer spacing of test holes, more sampling and testing than a site with few stratigraphic units that are continuous.
4. Environmental considerations.

B. Location of sites for logging and sampling

1. Evaluate information obtained under Item A above.
2. Determine the sample types to be obtained
   a. For any specific reach, consider whether coherent soils will be exposed at the toe and/or lower bank.
   b. If the answer under 2a is affirmative, plan undisturbed soil sampling of this and overlying coherent stratigraphic units.

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c. If the answer under 2a is negative, plan disturbed soil sampling of this and overlying stratigraphic units, whatever the characteristics of the latter.

C. Select equipment for logging and sampling

1. Choose backhoe or dragline for site investigations where possible and if water table is below invert.

2. Choose drilling equipment if depth is greater than practical for excavation equipment, because of high water table, or if in-place observations are unnecessary or impossible.

3. Select appropriate equipment and containers for undisturbed samples.

D. Data requirements at test holes

1. Log test holes (A suggested worksheet is included as Figure 3-3 of Chapter 3 (revised) TR-25) to depths of at least three feet below invert.

   a. Log test holes by stratigraphic units.

   b. Log appearance and condition in accord with ASTM D-2488 (Unified Soil Classification System).

2. Identify elevation of water table if encountered.

3. Record results of field tests.

4. Obtain representative samples of stratigraphic units. Sampling in undisturbed or disturbed state depends on determinations under IV B 2 above.

5. Supplement to site investigations plan.

   A break in continuity of stratigraphic units, changes in dispersion test results or other significant changes in soil characteristics between test holes requires an additional hole or holes to delineate changes.

F. Determine availability of bed material

1. Sand or gravel can aggrade an improved channel.
2. The hazard to the improved channel depends on whether expected flows will:
   a. Exceed the allowable tractive force for the characteristic grain sizes.
   b. The supply of bed material is sufficient to cause aggradation problems.
3. Measure or estimate depth of bed material in reach to be improved and in channel upstream. Note if bottom cannot be reached.
4. Obtain representative bed-material samples for determination of size distribution.

G. Define "clear water" or "sediment load" flow condition where required.

1. Evaluation of channel stability (allowable velocity or critical tractive force) may depend on how flow is classified.

2. For appropriate classification consider:

   a. Suspended sediment load records in the area.

   b. Severity of erosion in the watershed.

   c. Reservoirs or other structures affecting sediment load.

V. Site investigation report

A. Organization of field data

1. Adjust longitudinal profile of stratigraphic units prepared in tentative form as indicated in Item III B 4 to reflect more detailed observations under IV, Site Investigations.

2. Attach logs of test holes and results of field tests.

B. Report on findings

1. Prepare brief statement on site geomorphology to support delineations on longitudinal profile.

2. Prepare brief statement concerning findings under IV F. - availability of bed material.

3. Prepare brief statement on findings under IV.G. - "clear water" or "sediment load" flow conditions.

VI. Field and laboratory soil testing

A. Field testing

1. In-place density

2. In-place moisture content

3. Vane shear

4. Permeability

5. Dispersion of clay soils - Crumb test

B. Laboratory testing

1. Index tests

   a. Classification

      (1) Mechanical analysis

      (2) Liquid limit

      (3) Plastic limit

   b. Specific gravity

   c. Compaction

2. Engineering properties tests

   a. Strength

      (1) Unconfined compression

      (2) Direct shear

      (3) Triaxial shear

   b. Permeability

3. Other tests

   a. Shrink-swell

      (1) Shrinkage limit

      (2) COLE

      (3) Linear shrinkage

      (4) Free swell

   b. Soluble salts

   c. Base exchange

   d. Dry unit weight - natural moisture

   e. Dispersion

      (1) Laboratory dispersion test

(2) Crumb test

(3) Chemical tests